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HRXRD and TEM studies of cluster formation in LT GaAs.

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GaAs films grown by molecular beam epitaxy (MBE) at low temperature (LT GaAs) have attracted much attention due to high electrical resistivity and short carrier lifetime. Distinctive feature of this material is a large quantity of As antisites (As_{Ga}). The arsenic excess can be varied in a wide range by the growth temperature and As/Ga flux ratio, and also enhanced by isovalent indium impurity doping or reduced by doping with Be acceptors and Si donors. Upon annealing, the excess As segregates in clusters, size and concentration of which can be varied by annealing conditions. It should be noted that formation of As clusters does not deteriorate the crystallinity of the LT GaAs matrices either undoped or doped with In, Be, or Si [1–3].

In this paper we employ high resolution x-ray diffractometry (HRXRD) and transmission electron microscopy (TEM) to study structural transformations in LT GaAs films doped with isovalent Sb impurity.

The LT GaAs film doped with Sb ($\sim$ 1 at.%) as well as conventional (Sb-free) sample were grown by MBE at (200°C) on 2-inch GaAs(001) substrates. Both samples were divided into ten parts, one of which was kept as grown, the others were annealed in the MBE setup under arsenic overpressure at 500–880°C.

The HRXRD measurements of as-grown conventional LT GaAs showed lattice mismatch between the layer and substrate to be as high as $\Delta a/a = 8.4 \cdot 10^{-4}$. This value was in excellent agreement with As_{Ga} concentration of $7 \cdot 10^{19}$ cm^{-3}, witch was determined from the near-infra-red optical absorption study using Martin's calibration [4 ,5]. Multiple interference fringes at the x-ray rocking curve proved a high crystalline quality of the film. Reduced $\Delta a/a$ values were measured after anneals. That was the signature of transformation of As antisite defects to nanoscale As clusters. After anneal at 600°C, $\Delta a/a$ was close to zero. A system of nanoscale As clusters built in crystalline dislocation-free GaAs matrix was observed in the annealed samples by TEM.

The HRXRD measurements of as-grown Sb-doped LT GaAs showed multiple interference fringes and evidenced high crystalline quality of the film that was characterized by $\Delta a/a = 3.6 \cdot 10^{-3}$. After anneals at the temperatures of 500–700°C, the lattice mismatch decreased to $2 \cdot 10^{-3}$. The relaxation was much higher than what could be expected for the antisite defect concentration determined from optical measurements. We suggest that such a strong relaxation could be due to segregation of isovalent Sb impurity into the As clusters.

Another structural transformation was detected by HRXRD when the Sb-doped samples were annealed at the temperature higher than 700°C. It manifested itself by a strong broadening of the diffraction maximum related to the LT GaAs:Sb layer. The TEM study showed that the high temperature anneals result in formation of dislocation loops attached to the big As clusters. Thus, a new phenomenon was found, which originates from Sb doping of LT GaAs films. We may suggest that the break of crystallinity is due to incorporation of

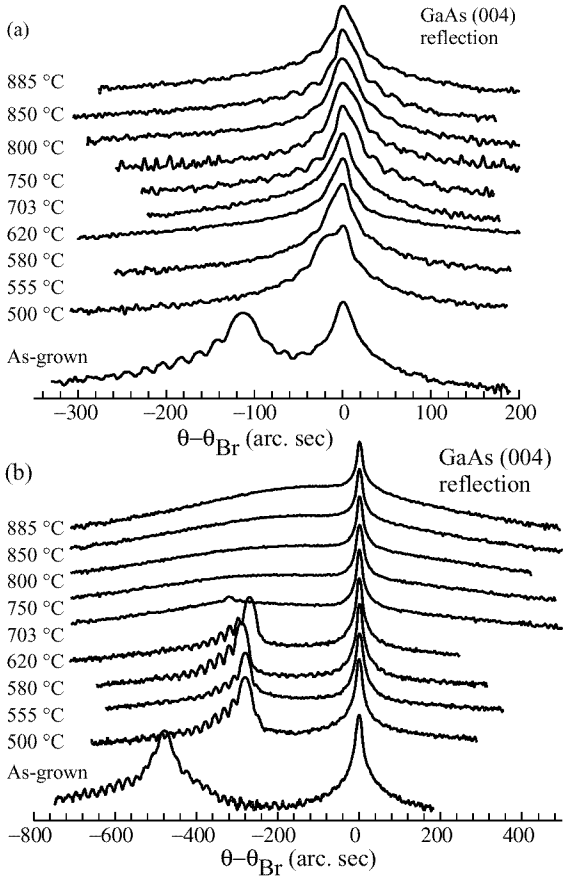

Fig. 1. X-ray rocking curves for conventional Sb-free (a) and Sb-doped (b) LT GaAs films annealed at various temperatures. The annealing temperatures are shown on the curves.

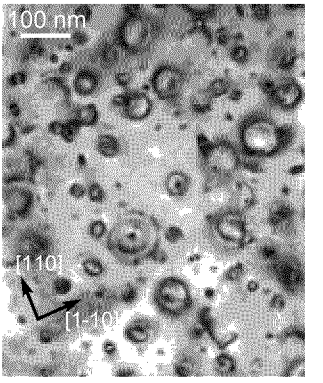

Fig. 2. Bright-field TEM image along [001] direction for Sb-doped LT GaAs film annealed at 703°C.

Sb in As clusters, so that big clusters induce fairly strong strains in the surrounding matrix.

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